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TRANSIENT ANALYSIS OF WIND TURBINE BLADES

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ABSTRACT

In this paper, transient analysis has been carried out on the blades to determine the strength of the blade for different blade materials, steel and composite materials ; E - Glass, carbon fibre and aramid fibre by applying wind loads. Fatigue analysis has been carried out to determine the life of the blades.

The results have been compared with all the materials with the help of applied boundary conditions.

KEYWORDS: Transient Analysis, Turbine Blades, Composite Materials, Von Mises Stress, Von Mises Strain & Total Deformation

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Original Article

INTRODUCTION

MODELING OF WIND TURBINE BLADES

The modeling of wind turbine has been carried out as per the specified geometry. The following figure 1, shows the 2-D model of wind turbine blades and figure 2, shows the 3-D model of wind turbine blades.

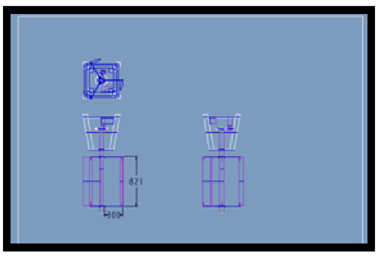


Figure 1: 2D Drawing

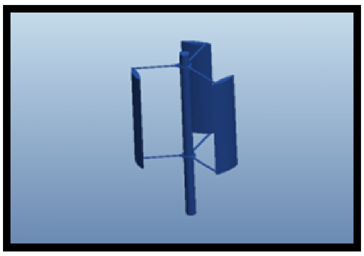


Figure 2: 3D Model of Wind Turbine Blades

TRANSIENT ANALYSIS OF WIND TURBINE BLADES

For the development of transient analysis of the wind turbine, meshing and boundary conditions should be given.

MESHING AND BOUNDARY CONDITIONS

The figure 3, shows the meshed model of wind turbine blades. For boundary conditions, the following procedure should be attempted in ANSYS. Select static structural right click → insert → select pressure and

displacement →

Select displacement → select required area → click on apply → put X, Y, Z component zero →

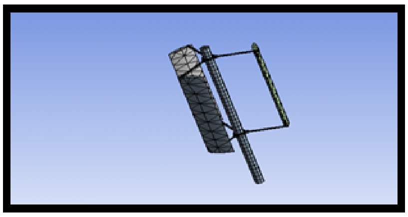


Figure 3: Meshed Model of Wind Turbine Blades

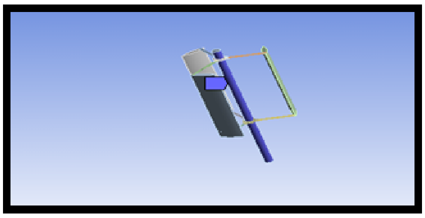


Figure 4: Pressure and Displacement

Applied Pressure Value 0.00482mpa and the displacement will come under safe value.

Select pressure → select required area → click on apply → enter pressure value 0.00482Mpa →

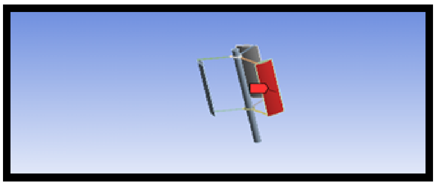


Figure 5: Required Area

Select rotational velocity→ enter velocity value 325.2 rad/sec

Select analysis setting→ enter step end time 0.001sec →enter the initial time setup 1 sec → enter the minimum time setup 1sec → maximum time setup 10sec.

RESULTS AND DISCUSSIONS

The following figures show the results, based on the applied boundary conditions for different materials. The total deformation, von Mises stress and von Mises strain can be found in the following analysis.

CASE.I.I.Material –Stainless Steel at 0.001 sec

Material properties of stainless steel

Density : 0.00000775kg/mm^3

Young’s modulus : 19300Mpa

Poisson’s ratio : 0.31

For the best strengthening of the wind turbine blades, the analysis can be compared with total deformation, von Mises stress and von Mises strain for the stainless steel material, at 0.001 sec.

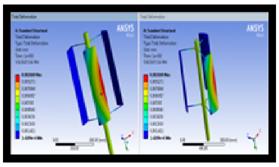
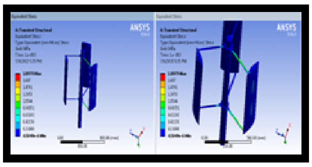
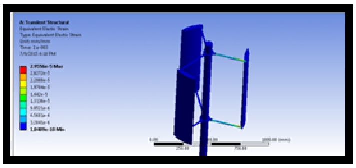




Figure 6: Total Deformation **Figure 7: Von Mises Stress** **Figure 8: Von Mises Strain**

CASE.I.II. Material –Stainless Steel at 0.002 sec

For the best strengthening of the wind turbine blades, the analysis can be compared with total deformation, i.e., von Mises stress and von Mises strain, for the stainless steel material at 0.002 sec.

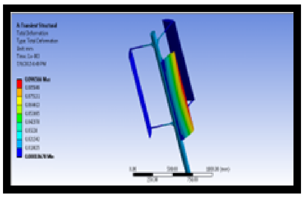
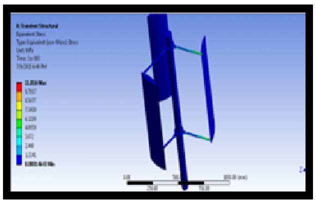
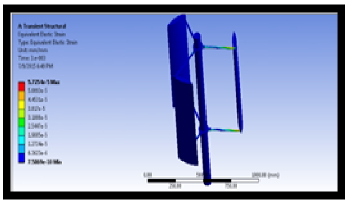




Figure 9: Total Deformation **Figure 10: Von Mises Stress** **Figure 11: Von Mises Strain**

CASE.II.I. Material –E-Glass fibre at 0.001 sec

Material properties of E-glass fibre

Density : 0.00000254kg/mm^3

Young's modulus : 73000Mpa

Poisson's ratio : 0.21

For the best strengthening of the wind turbine blades, the analysis can be compared with total deformation, i.e., von Mises stress and von Mises strain for the E-Glass fibre material at 0.001 sec.

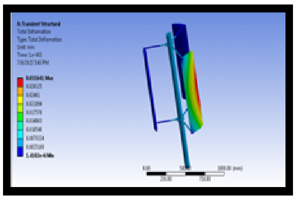
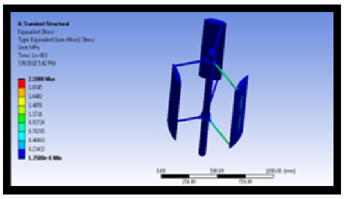
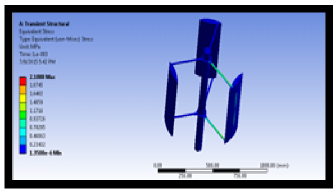




Figure 12: Total Deformation **Figure 13: Von Mises Stress** **Figure 14: Von Mises Strain**

CASE.II.II. Material –E-Glass fibre at 0.002 sec

For the best strengthening of the wind turbine blades, the analysis can be compared with total deformation, i.e., von Mises stress and von Mises strain for the E-Glass fibre material at 0.002 sec.

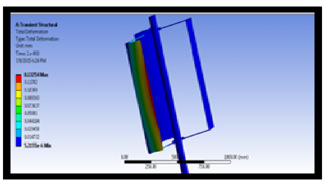
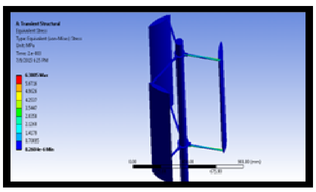
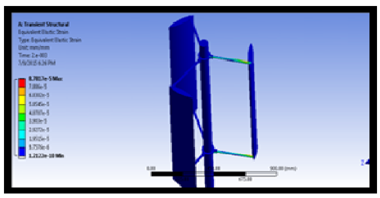




Figure 15: Total Deformation **Figure 16: Von Mises Stress** **Figure 17: Von Mises Strain**

CASE.II.III. Material –E-Glass fibre at 0.003 sec

For the best strengthening of the wind turbine blades, the analysis can be compared with total deformation, i.e., von Mises stress and von Mises strain for the E-Glass fibre material at 0.003 sec.

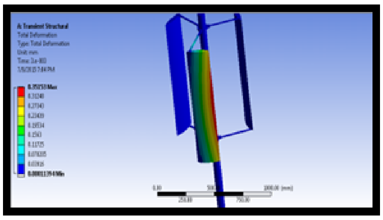
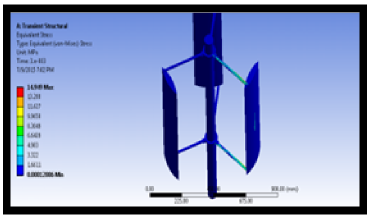
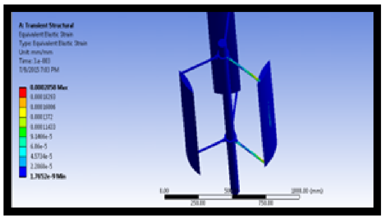
  

Figure 18: Total Deformation **Figure 19: Von Mises Stress** **Figure 20: Von Mises Strain**

CASE.III.I. Material –Carbon fibre at 0.001 sec

Material properties of Carbon fibre

Density : 0.00000175kg/mm^3

Young’s modulus : 181000Mpa

Poisson’s ratio : 0.3

For the best strengthening of the wind turbine blades, the analysis can be compared with total deformation, i.e., von Mises stress and von Mises strain for the Carbon fibre material at 0.001 sec.

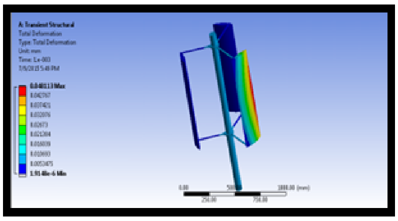
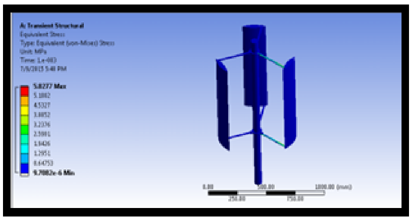
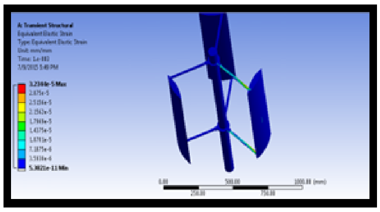
  

Figure 21: Total Deformation **Figure 22: Von Mises Stress** **Figure 23: Von Mises Strain**

CASE.III.II. Material –Carbon fibre at 0.002 sec

For the best strengthening of the wind turbine blades, the analysis can be compared with total deformation, i.e., von Mises stress and von Mises strain for the Carbon fibre material at 0.002 sec.

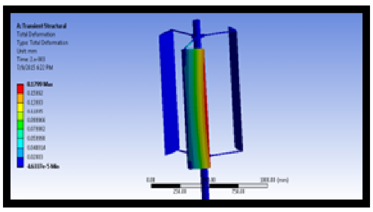
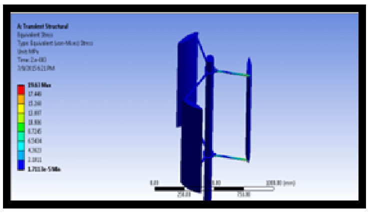
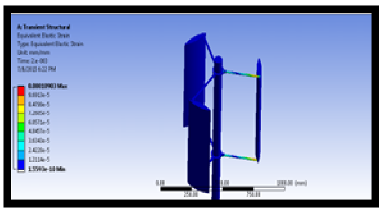
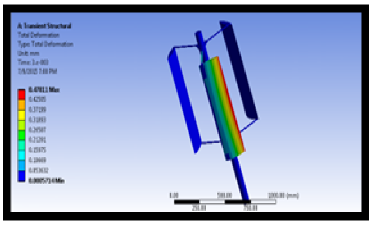
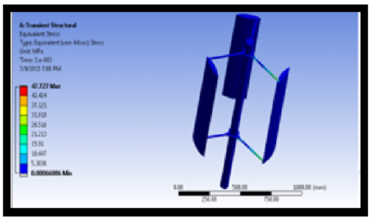
  

Figure 24: Total Deformation **Figure 25: Von Mises Stress** **Figure 26: Von Mises Strain**

CASE.III.III. Material –Carbon fibre at 0.003 sec

For the best strengthening of the wind turbine blades, the analysis can be compared with total deformation, i.e., von Mises stress and von Mises strain for the Carbon fibre material at 0.003 sec.





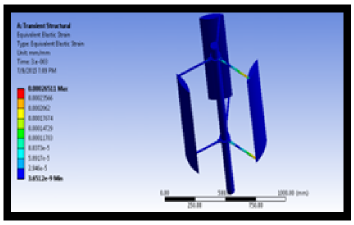


Figure 27: Total Deformation **Figure 28:Von Mises Stress** **Figure 29: Von Mises Strain**

CASE.IV.I. Material –Aramid (kevlar) at 0.001 sec

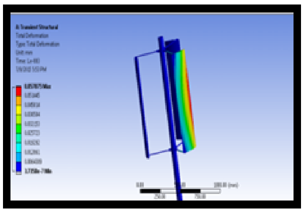
For the best strengthening of the wind turbine blades, the analysis can be compared with total deformation, i.e., von Mises stress and von Mises strain for the Aramid material at 0.001 sec.

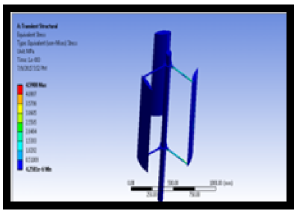
Material properties of Aramid

Density : 0.00000145kg/mm^3

Young's modulus : 112400Mpa

Poisson's ratio : 0.31





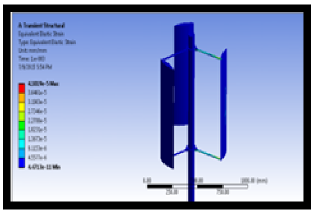
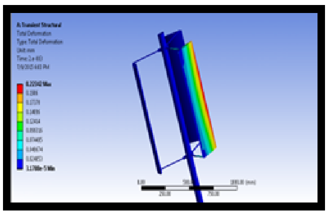
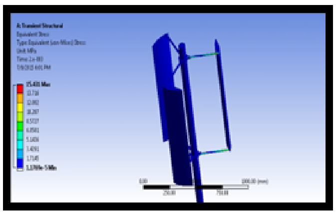


Figure 30: Total Deformation **Figure 31: Von Mises Stress** **Figure 32: Von Mises Strain**

CASE.IV.II. Material –Aramid (kevlar) at 0.002 sec

For the best strengthening of the wind turbine blades, the analysis can be compared with total deformation, i.e., von Mises stress and von Mises strain for the Aramid material at 0.002 sec





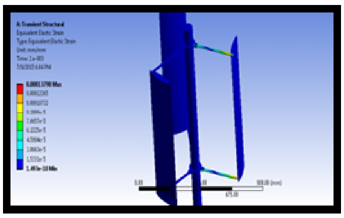
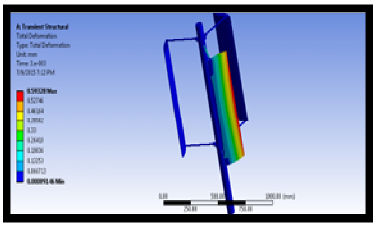
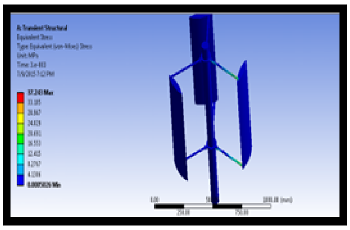


Figure 33: Total Deformation **Figure 34: Von Mises Stress** **Figure 35: Von Mises Strain**

CASE.IV.III. Material –Aramid (kevlar) at 0.003 sec

For the best strengthening of the wind turbine blades, the analysis can be compared with total deformation, i.e., von Mises stress and von Mises strain for the Aramid material at 0.003 sec





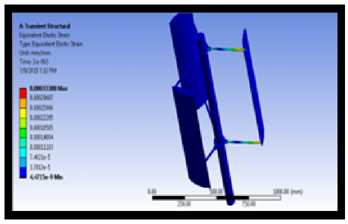
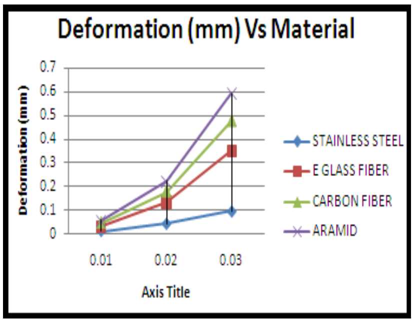


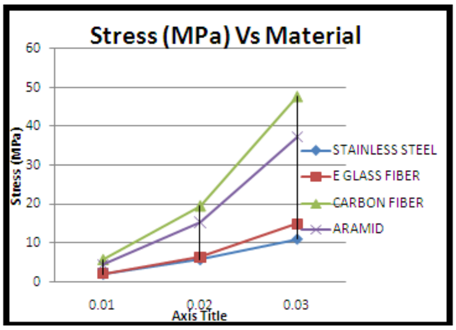
Figure 36: Total Deformation **Figure 37: Von Mises Stress** **Figure 38: Von Mises Strain**

TRANSIENT ANALYSIS RESULTS

Table 1: Transient Analysis Results

Material	Time (Sec)	Deformation (mm)	Stress(N/mm^2)	Strain
Stainless steel	0.001	0.01268	1.897	9.658e-6
	0.002	0.04345	5.688	2.955e-5
	0.003	0.09656	11.016	5.725e-5
E-glass fibre	0.001	0.03164	2.108	2.8998e-5
	0.002	0.13254	6.380	8.7817e-5
	0.003	0.35153	14.949	0.000205
Carbon fibre	0.001	0.04811	5.827	3.1344e-5
	0.002	0.17991	19.631	0.0001090
	0.003	0.47811	47.727	0.00026511
Aramid	0.001	0.05787	4.5908	4.1019e-5
	0.002	0.22342	15.431	0.0001367
	0.003	0.59328	37.243	0.0003308





Graph 1: Deformation vs Material **Graph 2: Stress vs material**

The graphs show the strengthening of stainless steel, E-Glass fibre, Carbon fibre and Aramid materials, for the applied boundary conditions. From the analysis, the E-Glass fibre can be suggested as the best material, for strengthening criteria to the applied boundary conditions.

CONCLUSIONS

Dynamic analysis has been carried out on the blades, to determine the strength of the blade for different blade materials, steel and composite materials E - Glass, carbon fibre and aramid fibre, by applying wind loads. The composite materials are considered due to their high strength to weight ratio, when compared with conventional metals. The wind turbine blades with composite materials have less weight, since their densities are lesser than that of metals. The stresses are far less than the respective allowable strength of all the composite materials. The stresses are less for E Glass fibre than

Aramid and Carbon Fibre. By observing the fatigue analysis results, the life is almost equal for all the materials. Due to the high strength of composite materials, the life of the blades will increase when they are used for more number of cycles and higher loads than steel. The blade will be damaged if the applied load is 31.689 times the present load, when steel and E Glass are used and blade will be damaged if the applied load is 31.171 times the present load, when Carbon Fibre and Aramid are used.

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